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HETERODERA CAROTAE: A DESTRUCTIVE NEMATODE OF CARROT.

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The carrot cyst nematode, ***Heterodera carotae***, was first described in England by Jones (9). Since then the nematode has been reported as the causal agent of carrot decline in Northern Ireland and Scotland (4). ***Heterodera carotae*** is also a pest on carrot in France, Italy, and Switzerland. Its geographic distribution includes West Germany, Portugal, The Netherlands, Sweden, East Germany, Czechoslovakia, Poland, Hungary, and Russia. Outside Europe ***H. carotae*** has been reported from Cyprus, India, and from Michigan (2,4).

Morphological Characters. ***H. carotae*** forms lemon-shaped cysts, smaller than those of most ***Heterodera*** species. It forms egg masses which may reach the same size as the cysts (Fig. 2).

Host Range. ***Heterodera carotae*** has a narrow host range. Jones (9) reported only cultivated and wild carrots as hosts for the nematode. However, the nematode also reproduces on some wild ***Umbelliferae***, such as ***Torilis leptophylla***, ***T. arvensis***, and especially on ***T. japonica*** (1).

Biology. Cyst eggs of ***H. carotae*** hatch only under the stimulus of root exudates of host plants (3,10), while egg mass eggs can hatch in water provided soil moisture and soil temperature are suitable (3). Emergence of second stage juveniles (J2) from eggs occurs at 5 C, but optimum temperature is in the range of 15-20 C. J2s may invade carrot roots at 8 degrees C, but further development was observed only at 10 C (6). Emerged J2s move through the soil until a suitable host plant root is found, which they then penetrate. ***H. carotae*** is a sedentary endoparasite. Once inside the root, the J2s undergo three additional molts. As they molt, juveniles become swollen and the adult females are white and lemon shaped (4) while the male is worm-like. After mating, the female produces a gelatinous matrix, in which 100 or more eggs are laid (Fig. 2). Eggs are also retained within the female's body which forms a brown cyst (Fig. 2). No intermediate yellow stage occurs. Females and cysts develop 26 and 36 days after carrot root invasion at 20 C (6). Eggs will undergo embryogenic development and egg mass eggs will hatch readily if soil moisture and soil temperatures are suitable, but eggs in the new cysts do not hatch during the first two months even in the presence of root exudate (3). Usually 1-2 generations are completed during a carrot growing season.

Symptoms and Damages. Nematode-infected carrots are stunted (Fig. 1A) with a reddish foliage. Tap roots are small and unmarketable (Fig. 1B), and have a bearded look because of the abnormal proliferation of rootlets (Fig. 1C). J2s infect rootlets only and never large tap roots. In the field, symptoms first appear in small, circular areas but may extend to the entire field, causing complete failure of a crop (Fig. 1A). Sections of infected roots show characteristic syncytia around the nematode head region, and large necrotic areas, causing disorder of the vascular system. Death of the distal part of the root may occur, which stimulates the plant to form new rootlets which, in turn,

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can be infected. The tolerance limit of carrot to *H. carotae* was found to be 0.8 eggs per cc of soil (5). In fields infested with 8, 16, and 32 eggs of *H. carotae* per cc of soil yield losses of 20, 50, and 80% occurred respectively (5). In most countries, damage by *H. carotae* occurs during spring and summer months, but in southern Italy severe damage occurs from September to June and not during the summer when high temperature limits egg hatch (6). Therefore, in Italy *H. carotae* may injure carrots in warmer areas where they are grown during the fall or winter.

Population Dynamics. Variation in population density of *H. carotae* is greatly affected by cropping systems and environmental conditions during the growing season. Reproduction rates 10 and 30 times greater than the nematode initial densities have been reported under field and microplot conditions (5). However, larger population densities were observed on late harvested carrots than on early harvested carrots. Harvesting carrots before the nematode completes its life cycle may result in decline of the population density 50-70% of that at planting, since the crop acts as a trap crop (8). Growing carrots when the soil temperature is 25 C suppresses nematode penetration and reproduction. Decline of *H. carotae* populations in the absence of a host ranges from 30-50% per year for cyst eggs and it is greater (6) for egg mass eggs.

Control. Generally, fumigant nematicides are more effective than nonvolatile nematicides. Nonvolatile nematicides give better control when split applications at planting and one month after emergence of carrots are used instead of single application at planting (8). There are no carrot cultivars resistant to *H. carotae*, but a 3-4 year crop rotation with non-host plants are effective because of the narrow host range. Growing early carrots and harvesting early are suggested to limit nematode population increase. A one-two month solarization (June-August) has provided satisfactory nematode control and yield increase of September carrot crop (7).

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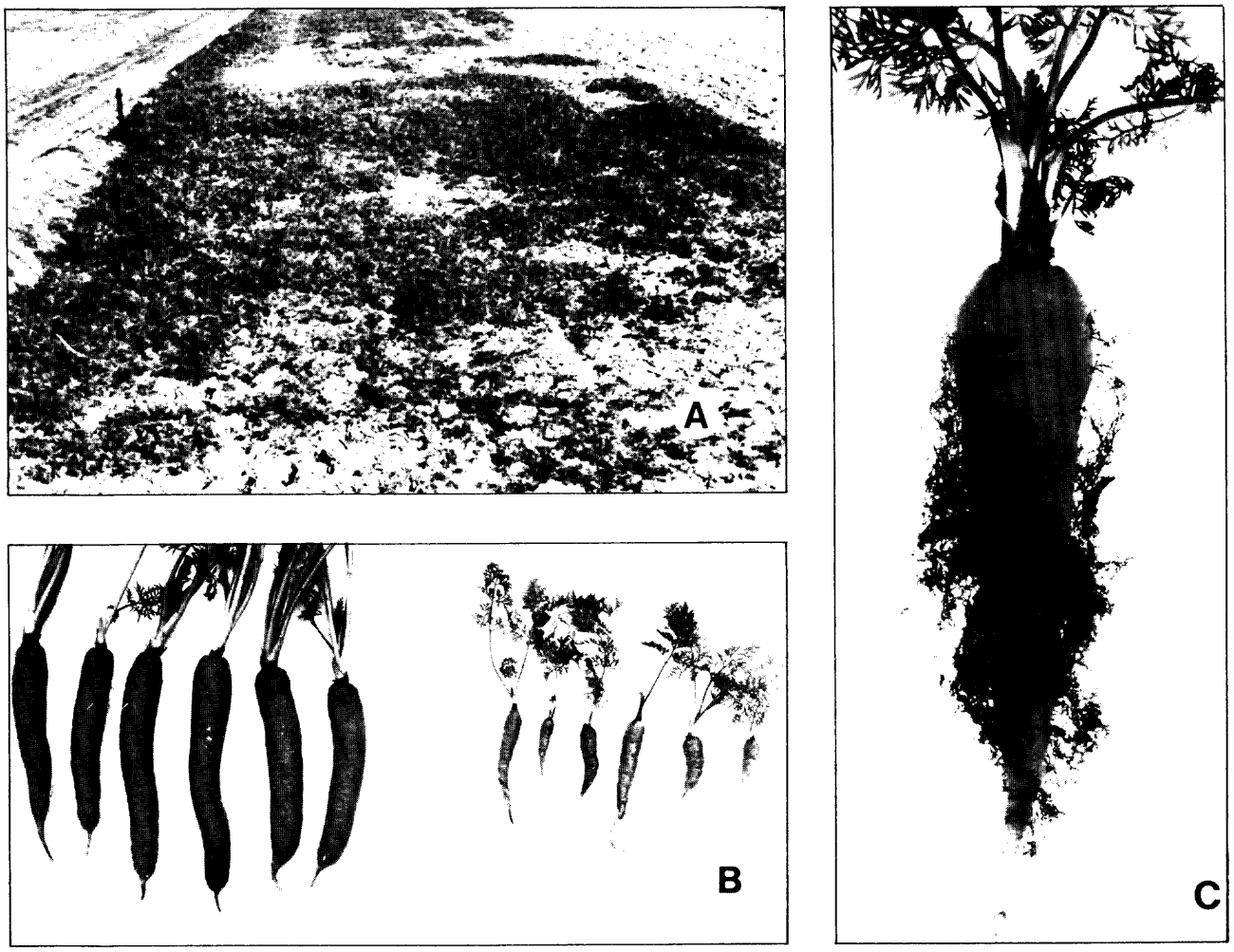

Fig. 1. Effect of ***Heterodera carotae*** on the growth of carrots. A) Nematode infested carrot field with stunted plants in large patches. B) Carrot plants of the same age infected (right) and non-infected (left) with the nematode. C) Nematode infected carrot root with abnormal rootlet proliferation.

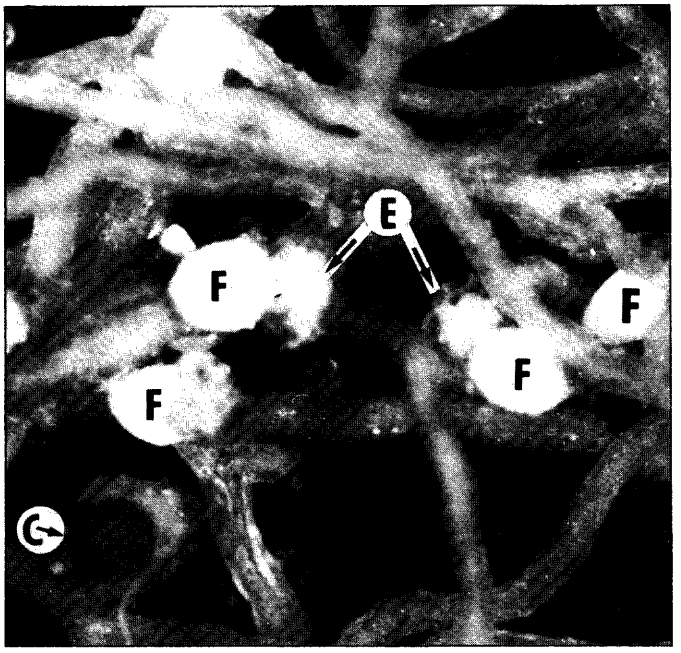

Fig. 2. Heterodera carotae females (F) and cyst (C) with egg masses (E) on carrot roots.

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